UV-Visible reflectance of Phobos from SPICAM and OMEGA and comparison with Deimos

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Introduction: Mars Express made several encounters with Phobos and a few with Deimos since 2004. Observations with SPICAM and OMEGA imaging spectrometers on board Mars Express covers the range from UV (110-312 nm) to visible and mid IR up to 5 µm. In the following we consider the ultraviolet (UV) channel of SPICAM and only the visible channel of OMEGA and its small UV extension down to 390 nm, in order to compare with SPICAM. Preliminary results were presented already in the past, e.g.[1]. Since then, a more detailed analysis was carried out, subtracting some internally scattered light affecting the SPICAM UV retrieved reflectance. Figure 1 shows the Phobos spectrum recorded by SPICAM at orbit 748 on August 20, 2004, at a low phase angle of 22° and 1248 km distance. Large oscillations observed in the spectrum are of solar origin. The subtracted stray light accounts for about 25% of the original spectrum. If not correctly accounted for, it would induce spurious oscillations in the reflectance spectrum.

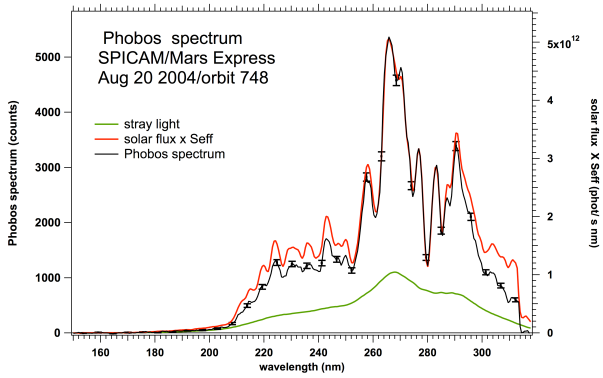

Figure 1. The SPICAM/MEX UV spectrum of Phobos (left scale in counts per 0.54 nm spectel, and error bars) is shown after subtraction of a model of stray light (green curve) derived from star observations. The red curve (right scale) is the solar spectrum multiplied by the sensitivity S_{eff} of SPICAM, mainly dictated by the CsTe cathode of the intensified detector.

UV reflectance of Phobos and Deimos: The reflectance $R(\lambda)=\pi\ B(\lambda)/(F_s\ (\lambda)\ \cos(sia))$, where $B(\lambda)$ is the brightness, $F_s\ (\lambda)$ is the solar flux at Phobos, and the angle of incidence *sia* at the observed point is determined from SPICE kernels geometry (Figure 2). With this refined analysis the UV reflectance below ~ 220 nm is flat (within error bars), and do not show any longer a broad absorption around 220 nm assigned to an organic material (PAH) as reported previously [1].

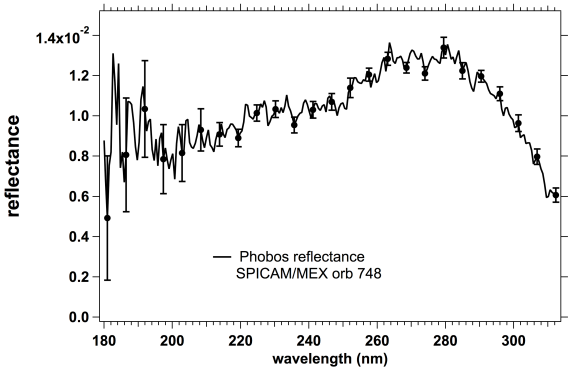

Figure 2. UV reflectance of Phobos (phase angle 22°) in the 180-312 nm range obtained by SPICAM at orbit 748. A systematic uncertainty of ± 20% should be added to the error bars which reflect measurements statistics.

Phobos is extremely dark in the UV, with a maximum reflectance of 1.2 % around 260-285 nm. Small wiggles are within statistical error bars, and likely not real. There is a strong decrease of the reflectance long ward of 280 nm, going down to 0.6% at 310 nm and confirming earlier SPICAM results [1], an untypical situation for small bodies (though present also in the clouds of Venus). The ratio of spectra of Deimos to Phobos is also displayed on figure 3, arbitrarily normalized to unity over the covered wavelength range. Wiggles are due to statistical noise gain. The overall shape of the ratio, with a slight decrease on both sides of a maximum, would suggest a similar spectral shape for both bodies, slightly enhanced for Deimos. Weathering by solar wind may have played a role to obtain such a low reflectance on both satellites of Mars.

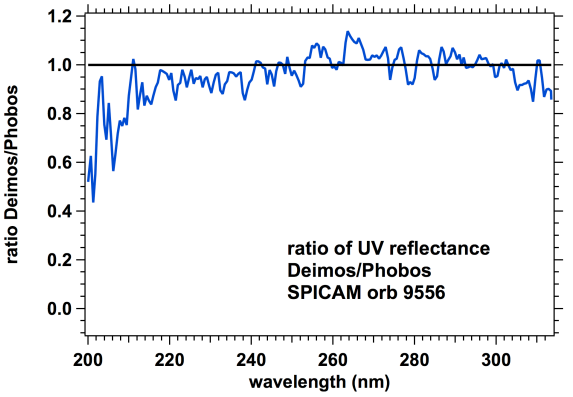

Figure 3. The normalized ratio of UV spectra of Deimos obtained by SPICAM at orbit 9556 to Phobos at orbit 748 in the 200-312 nm range.

Combined spectrum SPICAM/ OMEGA: During a close encounter (158 km) at orbit 756, both SPICAM and OMEGA made resolved measurements of the radiance factor Rad (classical I/F): Rad= π B(λ)/Fs (λ). Special care must be taken to combine measurements of the two imaging spectrometers which have different FOV, to ensure that the solar incidence angle, the phase angle and the emission angle are identical in the two wavelength domains. The radiance factor was averaged over the whole observation for the two instruments, in such a way that the radiance factors in the two wavelength domains are directly comparable. Figure 3 shows the combined spectrum.

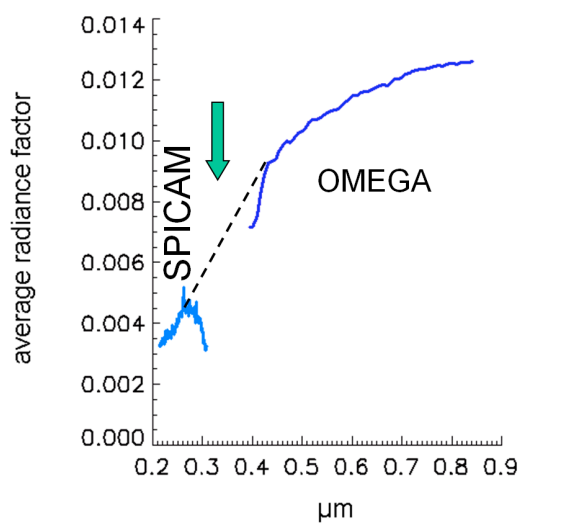

Figure 3. The combined spectrum of Radiance Factor from SPICAM and OMEGA suggests the presence of a deep absorption feature (green arrow). Both instruments, taken separately, support also this absorption feature.

In the UV the value of the radiance factor is ~ 0.005, smaller than the reflectance at 22° phase angle. This is because the area scanned during orbit 756 is not far from the terminator, and the solar incidence angle is large. There is a data gap between 312 nm (end of SPICAM) and 390 nm (short end of OMEGA). Still, both separately and in combination, the two sets of data strongly suggests that there is a 100-nm wide absorption feature centered at 350 nm and a depth up to 50 %, which was not reported in previous early HST UV observations [2]. A non-exhaustive comparison with some samples of a lab database [3] shows only a hint of resemblance with some type of ilmenites (not shown here), containing Fe and Ti oxides.

Discussion: In spite of the spectral gap between OMEGA and SPICAM, both instruments reveal a strong spectral dip in the UV reflectance of Phobos. This is in contrast with the Visible IR range (up to 3 μm) [4], where only two weak absorption features are detected by CRISM [5]. In the visible, one feature is centered at 0.65 μm, with an absorption depth varying from 0 to 4%. The strongest visible absorption is found in the so-called "red-units" of Phobos, and seems ubiquitous on Deimos [5]. The 2.8 μm is from 1 to 10 % deep. The Phobos red unit shows on average deeper 0.65 μm and 2.8 μm bands, whereas Phobos blue unit have no 0.65 μm band and a weaker 2.8 μm band. Deimos has 2.8 μm band depths comparable to the deepest Phobos red unit [5]. These two Visible IR features were interpreted [5] either to highly desiccated Fe-phyllosilicate minerals indigenous to the bodies, or to a surface process involving Rayleigh scattering and absorption of small iron particles formed by exogenic space weathering processing.

In this rather uncertain situation, the UV band detected by SPICAM and OMEGA on board Mars Express is of great importance to attempt discriminating between the two scenarios proposed above to explain the Visible-IR reflectance spectra of Phobos and Deimos. It stresses the importance of this strongest UV spectral feature which deserves more studies and observations to fill the remaining gap from 312 to 390 nm. It is hoped that the IUVS instrument on board MAVEN will greatly contribute in this respect [6].

Concerning the Deimos-Phobos comparison, we note that the UV signature of Deimos seems enhanced with respect to Phobos, in line with what is found for the 0.65 μm and 2.8 μm absorption bands [5].

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